Status of the RF System

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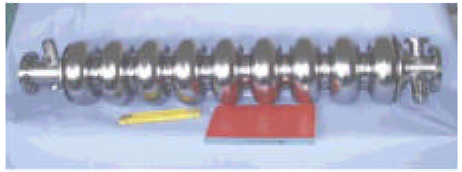
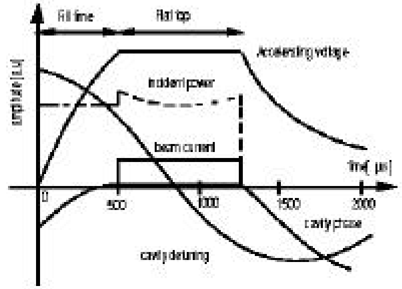
- TESLA RF Requirements
- RF Station Layout
- Status of the RF Components
  - Klystron
  - Modulator
  - HV Pulse Cable
  - RF Waveguide Distribution
  - LLRF
- Summary

TESLA 500 RF Requirements

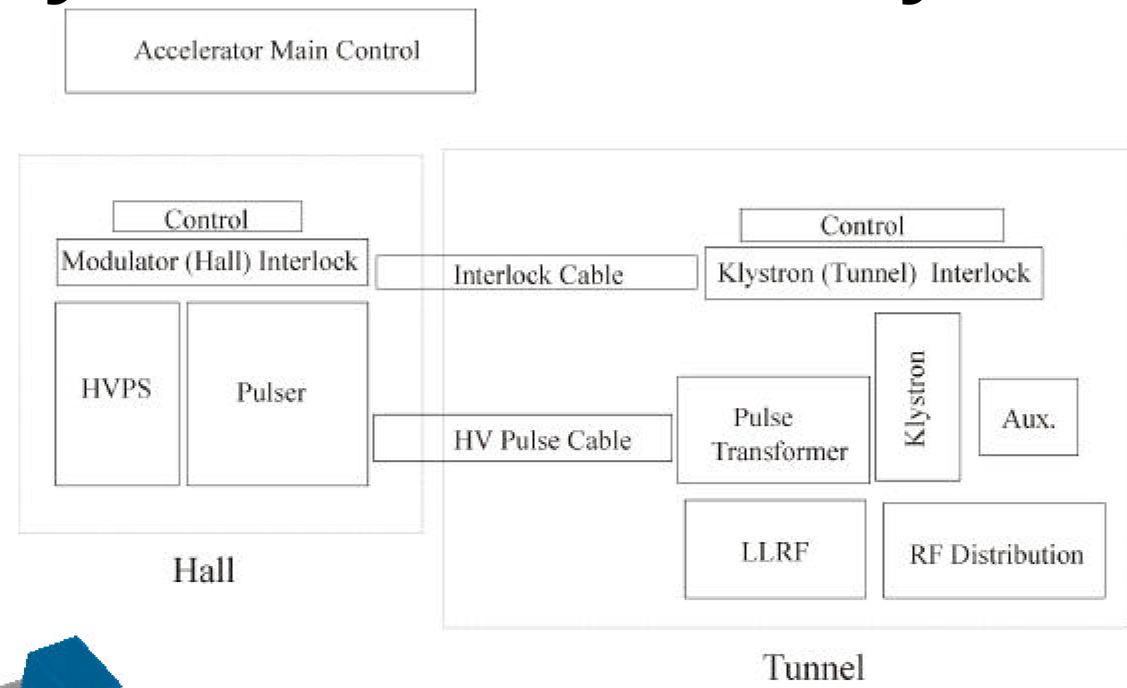


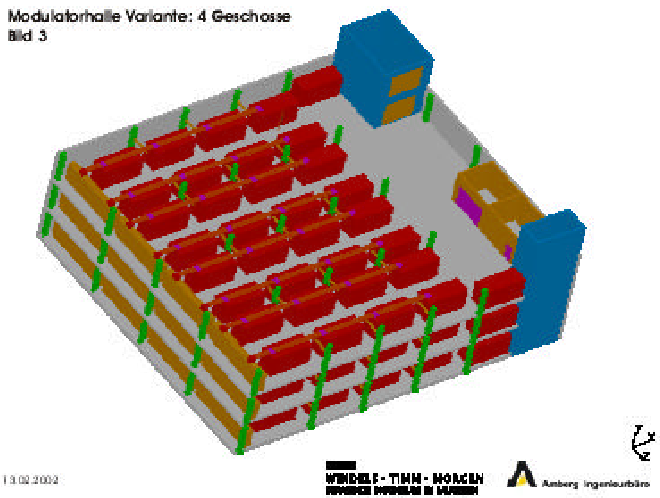
Number of sc cavities:	21024 total
Power per cavity:	231kW
Gradient at 500GeV:	23.4MV/m
Power per 36 cavities (3 cryo modules):	8.3MW
Power per RF station:	**9.7MW** (including 6% losses in waveguides and circulators and a regulation reserve of 10%)
Number of RF stations:	**572**
Macro beam pulse duration:	950µs
RF pulse duration:	**1.37ms**
Repetition rate:	**5Hz**
Average RF power per station:	**66.5kW**

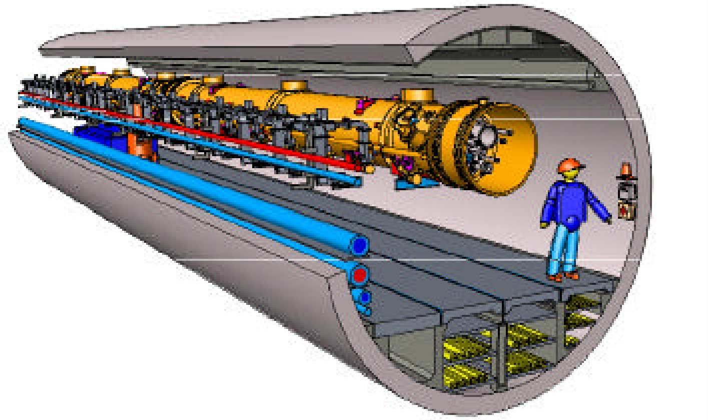


For TESLA 800 the number of stations must be doubled. The gradient is 35MV/m.

Layout of the RF-System



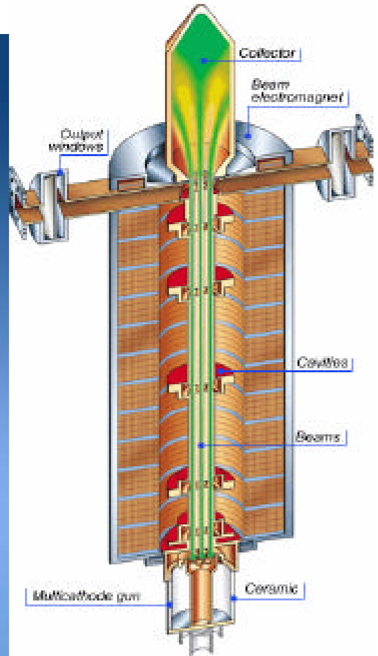




Multi Beam Klystron THALES TH1801

Measured performance

Operation Frequency:	1.3GHz
Cathode Voltage:	117kV
Beam Current:	131A
Number of Beams:	7
Cathode loading:	5.5A/cm^2
Max. RF Peak Power:	10MW
RF Pulse Duration:	1.5ms
Repetition Rate:	10Hz
RF Average Power:	150kW
Efficiency:	65%
Gain:	48.2dB
Solenoid Power:	6kW
Length:	2.5m
Lifetime:	~40000h



Multi Beam Klystron THALES TH1801 cont.

- 3 klystrons have been manufactured
- The prototype PT has been in operation at TTF since May 2000 and has 14000h operation hours
- Series klystron #1 has been returned to the vendor after ca. 3000h (gun arcing)
- Series klystron #2 has been tested and returned to the vendor
- Gun arcing has been investigated, the problem is identified and modifications are underway
- Modified klystrons #1 and #2 are expected back at DESY after May 2004
- More klystrons have been ordered

Multi Beam Klystron CPI VKL-8301

Design Features:

•6 beams

•HOM input and output cavity

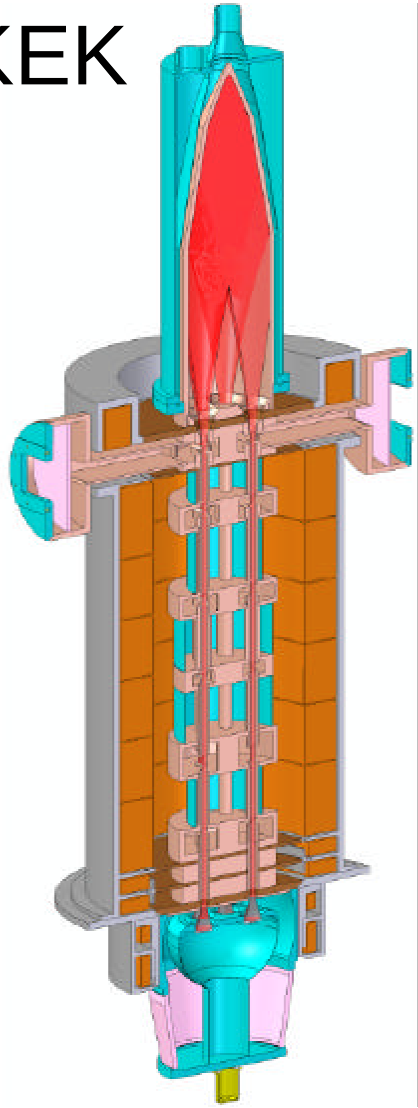
•Cathode loading: <2.5A/cm^2
lifetime prediction: >100000h

Status:

•Bakeout in February 2004

•Test at CPI started March 22, 2004

The TOSHIBA E3736 MBK
in cooperation with KEK



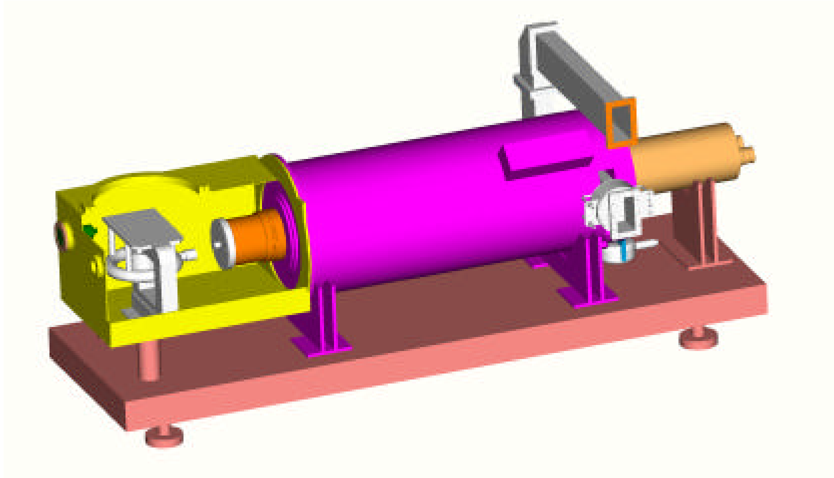
Design Features:

- 6 beams
- Ring shaped cavities
- Cathode loading: <2.1 A/cm^2

Status:

- Bakeout scheduled for April 2004
- Test scheduled for April/May 2004

Horizontal Klystron



- Modification towards a horizontal version is straightforward
- Horizontal klystrons are already in use e.g. the LEP klystrons at CERN or the B-factory klytrons at SLAC
- One vendor has already designed a horizontal version

Klystron Replacement

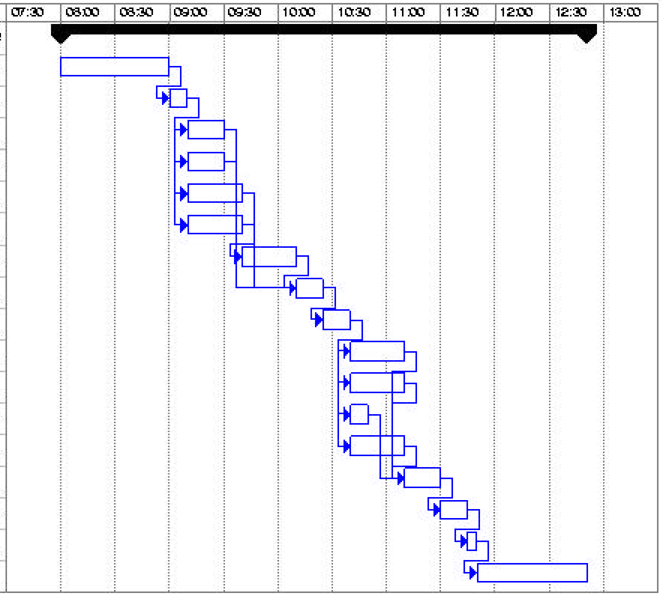
• the klystron lifetime will be determined by the cathode lifetime since other klystron components are operated at a moderate level

•with a klystron lifetime of 40000h and an operation time of 5000h per year 8 klystrons must be replaced during a monthly access day

•an overhead of 12 klystrons will be installed, therefore no degradation of accelerator performance is expected between two access days

•teams of 3-4 people will exchange a klystron within a few hours; klystrons will be equipped with connectors (HV, controls, cooling, waveguides) which allow fast exchange of a klystron in the tunnel

Nr.	Vorgangsname	Dauer
1	**Klystron Exchange Main LINAC**	**0,2 Tage**
2	Transportation to tunnel position	60 Min.
3	Local breakers to change mode	10 Min.
4	Disconnect HV coax cable	20 Min.
5	Disconnect local controls	20 Min.
6	Disconnect water cooling system	30 Min.
7	Disconnect two waveguides	30 Min.
8	Unexpected events	30 Min.
9	Remove klystron	15 Min.
10	Put klystron into positon	15 Min.
11	Connect two waveguides	30 Min.
12	Connect the water cooling system	30 Min.
13	Connect local control	10 Min.
14	Connect HV coax cable	30 Min.
15	Check all above again	20 Min.
16	Unexpected events	15 Min.
17	Local breakers to operation	5 Min.
18	Transportation out of the tunnel	60 Min.

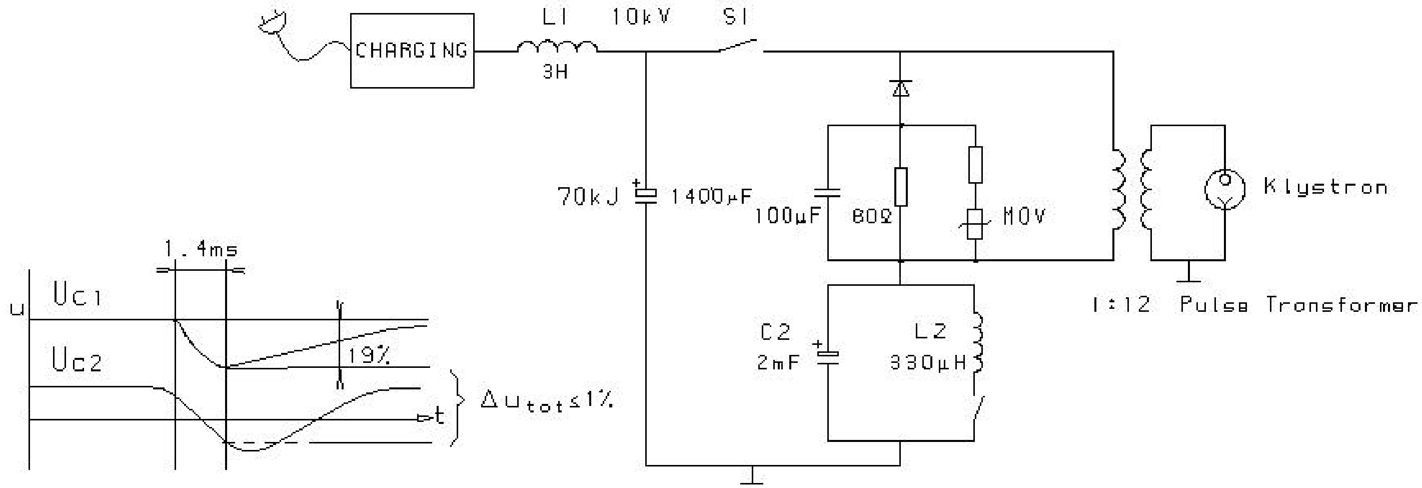


Klystron Status Summary

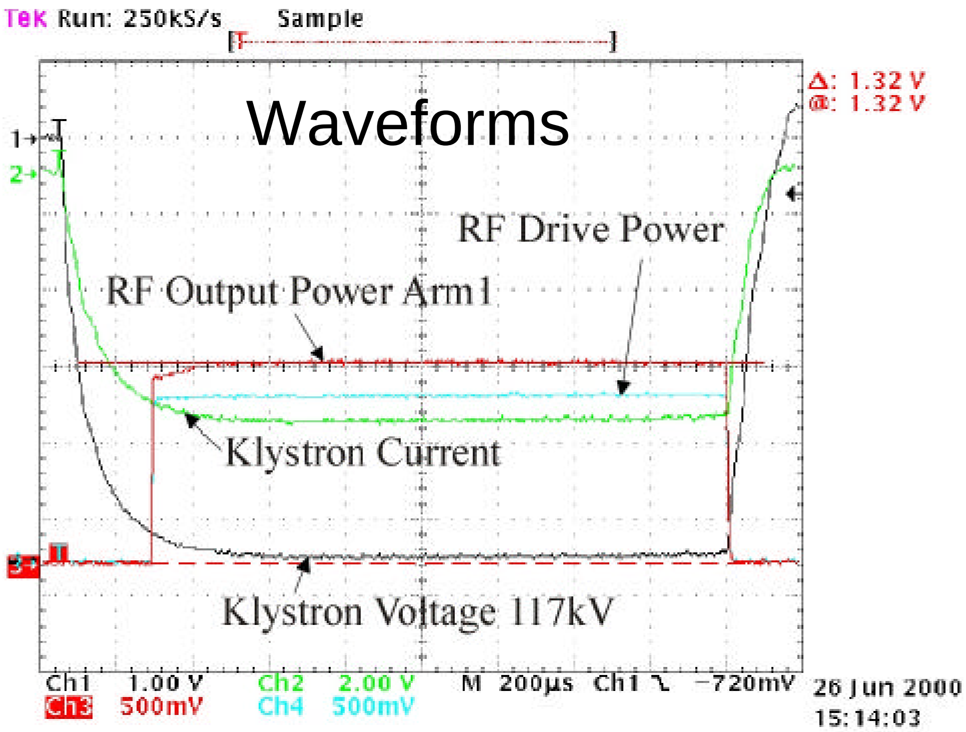
- Multi beam klystrons have been in use at TTF since 2000, gun arcing has been investigated, the problem is identified and modifications are underway
- 3 vendors have already manufactured or are near to manufacture klystrons meeting the TESLA klystron requirements
- Lifetime of the klystron is expected to be >40000h limited by cathode lifetime, for cathode current densities <2.5A/cm^2 the lifetime might be >100000h
- Layout for horizontal tunnel installation which allows fast exchange of a klystron is straightforward

Modulators

- Modulators must generate HV pulses up to 120kV and 140A, 1.57ms pulse length and 5Hz repetition rate
- The top of the pulse must be flat within 1%
- The bouncer type modulator with its simple circuit diagram was chosen for TESLA



The FNAL Modulator



•3 modulators have been developed, built and delivered to TTF by FNAL since 1994

•They are continuosly in operation under different operation conditions

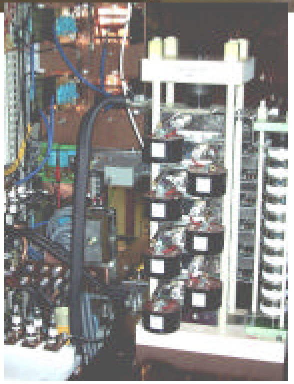
FNAL Modulator at TTF

Industry made Modulator

PPT Modulator

- Industry made subunits (PPT, ABB, FUG, Beerwald)
- Constant power power supply for suppression of 5Hz repetition rate disturbances in the mains
- Compact storage capacitor bank with self healing capacitors
- IGCT Stack (ABB); 7 IGCTs in series, 2 are redundant

HVPS and Pulse Forming Unit



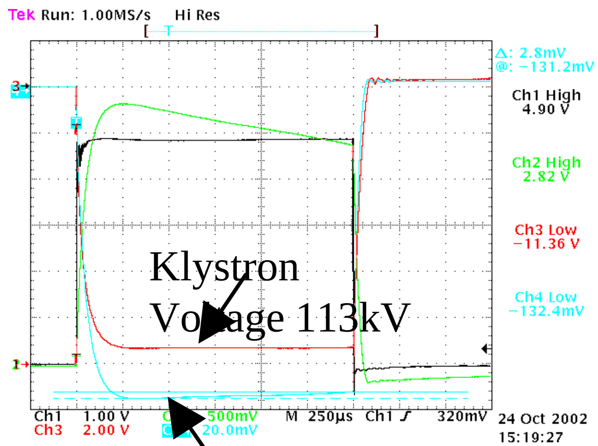
IGCT Stack

Industry made Modulator cont.

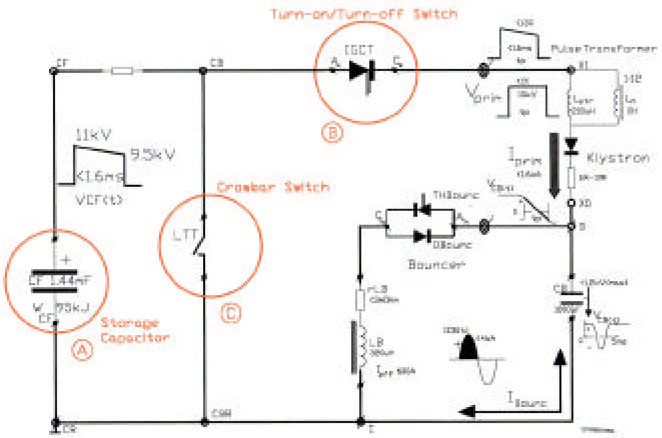
•Low leakage inductance pulse transformer (ABB) L<200µH resulting in shorter HV pulse rise time of <200µs

•Light Triggered Thyristor crowbar avoiding mercury of ignitrons

Pulse Transformer



Klystron Current 132A



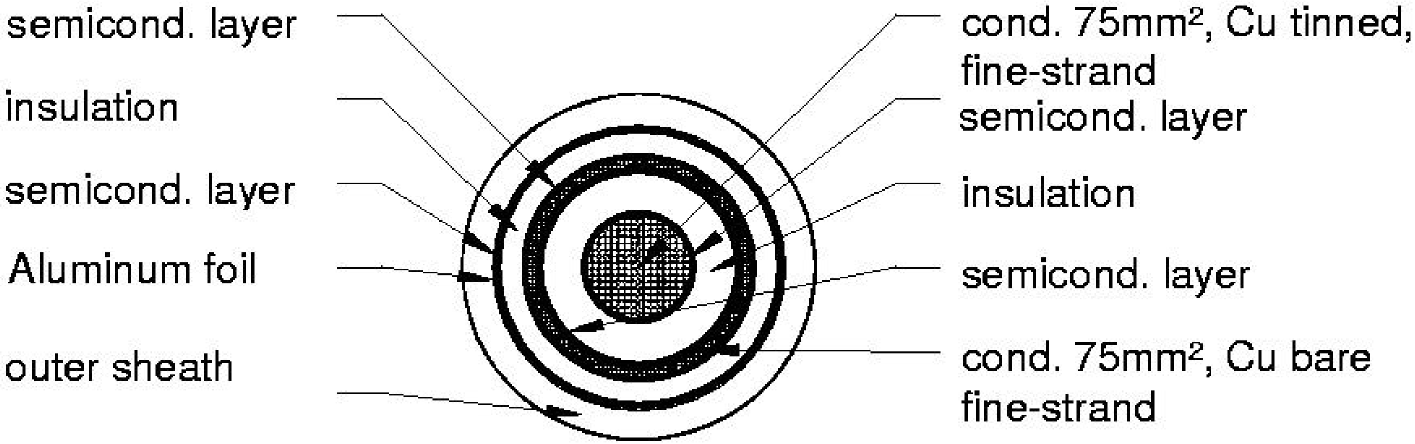
Modulator Status

- 10 Modulators have been built, 3 by FNAL and 7 by industry
- 7 modulators are in operation
- 10 years operation experience exists
- Work towards a more cost efficient and compact design has started
- Many vendors for modulator components are available

HV Pulse Cable

- Transmission of HV pulses (10kV, 1.6kA, 1.57ms, 5Hz) from the pulse generating unit (modulator hall) to the pulse transformer (accelerator tunnel)
- Maximum length 2.8km
- Impedance of 25 Ohms (4 cable in parallel will give 6.25 Ohms in total) to match the klystron impedance
- Triaxial construction (inner conductor at 10kV, middle conductor at 1kV, outer conductor at ground)

HV Pulse Cable cont.



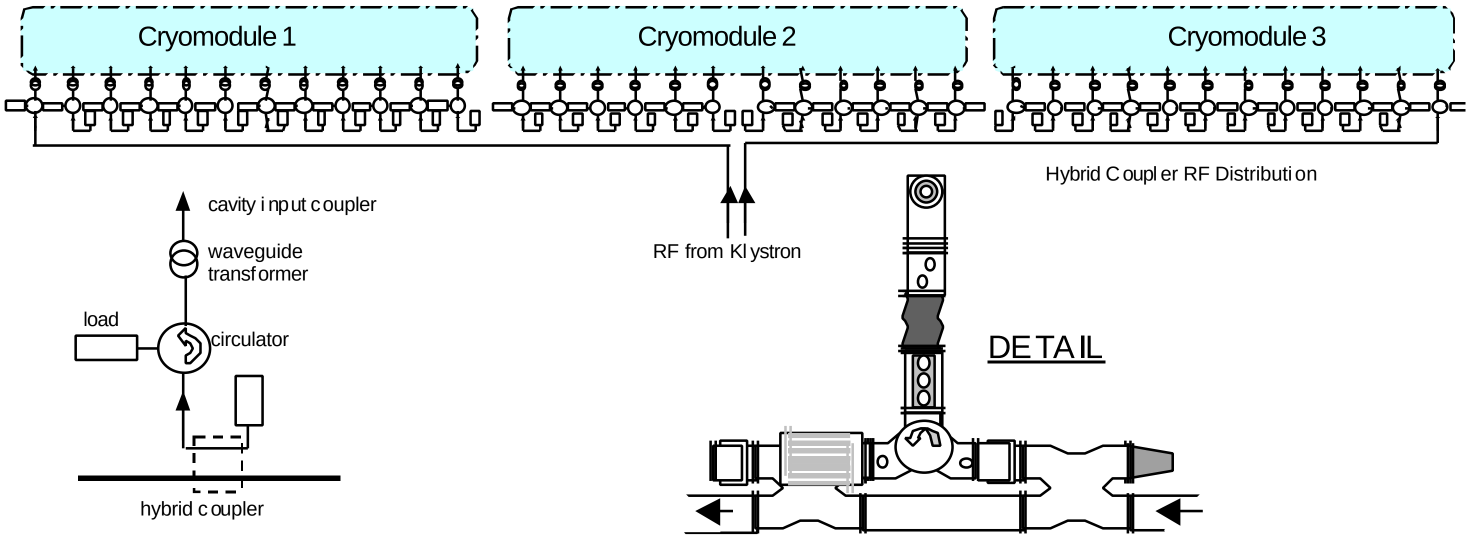
diameter 30mm
dielectric material: XLPE

HV Pulse Cable cont.

- Prototype cable has been delivered and test is scheduled at TTF for May 2004
- Experience with similiar cables in Europe and USA exists. Taking into account these data we expect 1 fault per year.
- Minimum lifetime of the cables is 10^{10} pulses =111 years

RF Power Waveguide Distribution

- Distribution of klystron output power to the superconducting cavities
- Protection of the klystron from reflected power
- Control of phase and Q_{ext}



RF Waveguide Components

for operation with air

3 Stub Tuner (IHEP, Bejing, China)

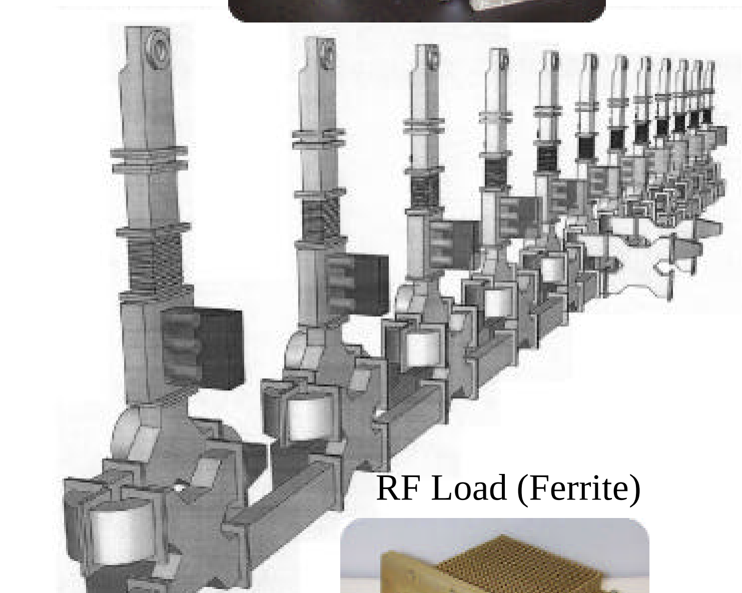
Changing phase, degree	±60
Impedance matching range	$1/3Z_w \div 3Z_w$
Max power, MW	2

* Z_w – waveguide impedance

Hybrid Coupler (RFT, Spinner)

Directivity, dB	≥30
Return loss, dB	≥35
Coupling factor, dB (due to tolerance overlapping only 13 different coupling factors instead 18 are nessesary)	12.5; 12.0; 11.4; 10.7; 10.1; 9.6; 9.1; 8.5; 7.8; 7.0; 6.0; 4.8; 3.0
Accuracy of coupling factor, dB	±0.2

E and H Bends (Spinner)



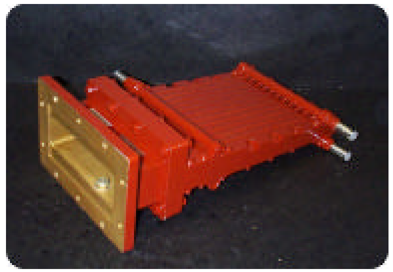
RF Load (Ferrite)

Type	WFHLL 3-1
Peak input power, MW	1.0
Average power, kW	0.2
Min return loss at 1.3GHz, dB	32÷40
Max VSWR at 1.3 GHz	<1.05
Max surface temperature, ΔT °C (for full average power)	50
Physical length, mm	230

Circulator (Ferrite)

Type	WFHI 3-4
Peak input power, MW	0.4
Average power, kW	8
Min isolation at 1.3 GHz, dB	□30
Max insertion loss at 1.3 GHz, dB	□0.08
Input SWR at 1.3 GHz (for full reflection)	1.1

RF Load (Ferrite)



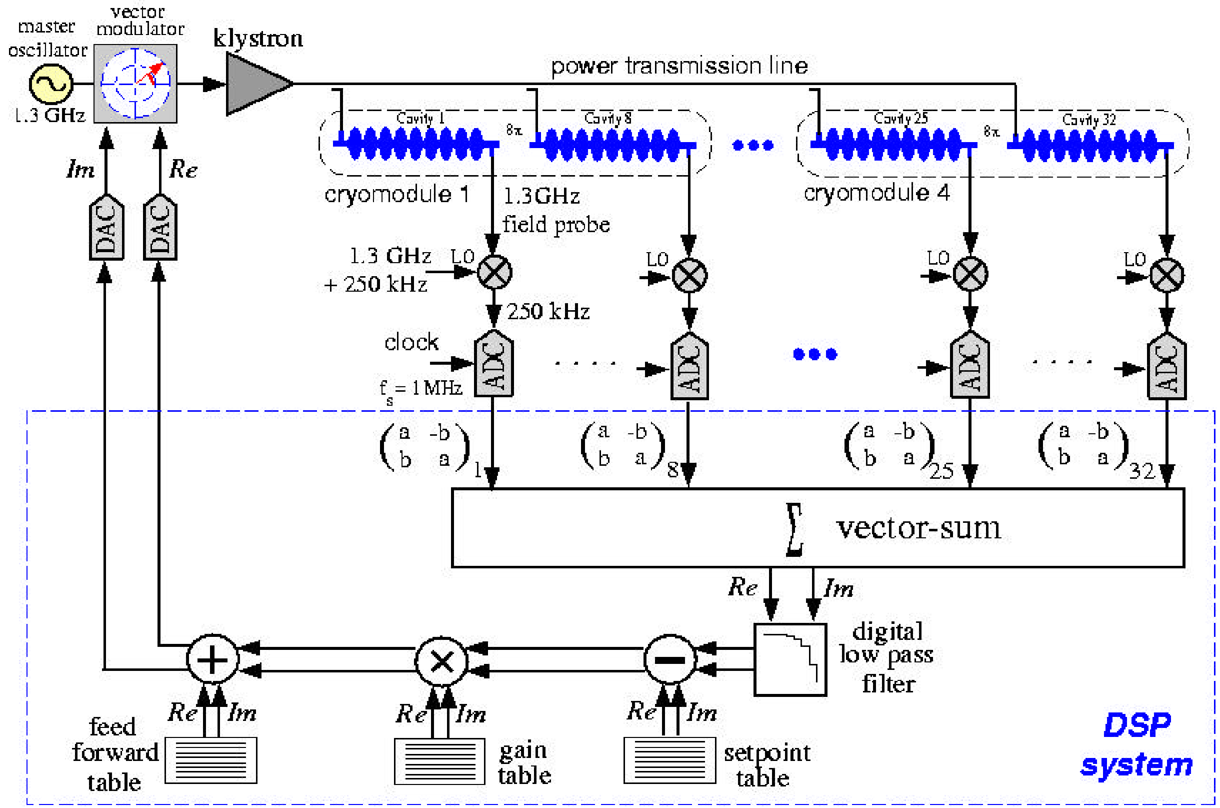
Type	WFHL 3-1	WFHL 3-5
Peak input power, MW	2.0	5.0
Average power, kW	10	100
Min return loss at 1.3 GHz, dB	32÷40	32÷40
Max VSWR at 1.3 GHz	<1.05	<1.05
Max surface temperature, ΔT °C (for full average power)	20	30
Physical length, mm	385	850

RF Waveguide Distribution Status

- Waveguide components for TESLA have been developed in cooperation with industry or are standard of the shelves components
- Operation experience of 10 years from TTF
- Development of integrated components has been started (e.g. circulator with integrated load)
- Development of a high power circulator for operation with air has been started

LLRF

- Digital system
- Feedback plus feedforward
- Extensive diagnostics and exception handling



LLRF cont.

- Amplitude and phase control have been demonstrated with beam during linac operation; amplitude stability: $5x10^{-3}$, phase stability: 0.5°
- Several years of operation experience
- LLRF understood
- Final design and optimization are underway

Summary

- All main components for the TESLA RF system are available today
- The HV pulse cable prototype has been manufactured and test is scheduled
- For all components at least two vendors are available and many components are standard catalog products
- Improvements for more cost efficient and enhanced reliable components are underway